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ABSTRACT

For teachers concerned about the underrepresentation of Hispanics and Native Americans in science fields, this paper provides resource materials and instructional approaches. First, the role of ethnocentrism in determining what is included in science courses is discussed; the non-Western impact of science has been systematically ignored, it is argued, but its contributions to civilization have important implications for both minority and majority students. The remainder of the paper discusses a variety of topics, including Mayan mathematics and the Mayan calendar, the Horizon Coordinate System (used by ancient astronomers), Mesoamerican buildings and structures used for astronomical purposes, and ideas for culturally relevant student projects in astronomy, geology, botany, agriculture, nutrition, architecture and city planning, and art. Twelve figures illustrating the discussion of astronomy and time-keeping are included and a bibliography is appended. (KH)

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TEACHING CULTURALLY RELEVANT SCIENCE

Presented at the Michigan Annual Hispanic Education Conference. Dearborn, MI. May 13-14, 1983.

by

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TEACHING CULTURALLY RELEVANT SCIENCE

Not since the Sputnik era has there been such an interest in the problems facing science education. Its scale and complexity may exceed that of the Sputnik era. The problem is being addressed at the National, State and Local levels. While it is not within the scope of this paper to address the background of the problems facing science education, it is important to recognize two important differences between the time of Sputnik and today, differences which have significant implications for the minority communities:

1. Today there is a recognition that science education must do two things: a. train more scientists and b. develop a scientifically literate population.
2. Today there is a consideration for underrepresented groups such as women and minorities ,albeit, not always mentioned in specific terms.

Hispanics and Native Americans are greatly underrepresented in science. Among the reasons given for this is a lack of role models. This is due not only to the scarcity of scientists in these groups but also of intellectual models.There is a presumption on the part of the schools that these cultures are either anti-scientific or at best a-scientific. On the other hand there is a common belief that the Western cultural heritage is particularly propitious to scientific development (Butterfield 1965: 187-200). Lynn White (1967) traces this attitude to early medieval times, when the discovery of the mold-board plow changed man's relationship to the soil- from being a part of nature to being an exploiter of nature. If this were true, where does it leave all of the cultures of the New World which never used a plow because they lacked animals to pull it? Another factor identified by White is that, "...Christianity especially in its Western form is the most anthropocentric religion the world has ever seen...it established a dualism of man and nature but also insisted that it is god's will that man exploit nature for his proper end... By destroying pagan animism, Christianity made it

possible to exploit nature in a mood of indifference to the feelings of natural objects.'

Most of the material available on the development of science reflects this ethnocentric orientation. The scientific contributions of China, India and Islam are usually minimized ,and traditional native cultures are usually depicted as permeated with superstition and magic, and thus not oriented toward science (narrowly defined). This can be used in turn to attribute the small number of minority scientists to a deficiency in their own cultural background ,exculpating thus the larger society.Octavio Romano (1973 :30-36) has shown that value-laden research in the social sciences has contributed to building a stereotype about Mexican-Americans and their culture.Attributed characteristics, such as a present-time orientation rather than a future-time orientation , are then blamed for their lack of advancement in society. This same type of ethnocentrism has resulted in the attribution of the "scientific" aspects of Mexican folk medicine, such as the "hot-cold" concept ,to an European origin ,while attributing "superstitious" concepts, such as the existence of witchcraft, to an Indian origin (Foster 1978).Ortiz de Montellano has shown elsewhere (1976a) that at the time of the conquest, the exact opposite could have been equally plausible.

The entire area of the scientific validity of the beliefs of native peoples and the rationality of their thinking processes needs to be examined carefully. We should not be trapped by excessively restrictive definitions of what constitutes science. Malinowski used the following as a minimal definition (1954:34),"... a body of rules and conceptions,based on experience and derived from it by logical inference, embodied in material achievements and in a fixed form of tradition and carried on by some sort of social organization ..." He found that many principles of native knowledge were scientific by this definition ,and even when the following additional requirements were imposed, " ...the rules of science must be laid down explicitly, open to control by experiment and critique by reason. They must not only be rules of practical behavior, but

theoretical laws of knowledge...." (1954:34).On occasion valuable empirical knowledge can be obtained ,even if the goal differs from that of modern science to some extent.The astronomer Antony Aveni points out that, " We are trying to understand our relationship with the natural world and control our environment. The Mayas hoped to predict the negative forces in the world so that they could be avoided."(Cornell 1981 : 119).The Mayans were sophisticated observers of nature ,which will be demonstrated below through a discussion of the accuracy of the astronomical alignments of their buildings and of the sophistication of their calendar. In our own research, we have found that the Aztecs were accurate observers of the physiological effects of plants and could obtain the effects required by their etiological beliefs (Ortiz de Montellano 1975 ; Ortiz de Montellano and Davidson 1983).

The purpose of this paper is to help science teachers to address the problem, in particular on how to impact the minority communities, especially the Hispanic. Its aim is to provide teachers with resource material and approaches which will enable the students to:

1.develop pride in their cultures' contribution to science.
2.learn science from a familiar cultural base.
3.Find a motivation to choose science as a career.
4.recognize the importance of science in their lives.

While other approaches have not used a cultural context, they have recognized that in the teaching of science one must accept student interest as it exists and one must lead the students into areas that are necessary for either a career in science or for scientific literacy as a citizen.The non-Western impact of science has been systematically ignored in the teaching of science probably because the formidable advances in the non-western world did not evolve into modern science as happened in Europe's scientific revolution. For example, until the sixteenth and seventeenth centuries of the common era, the Chinese were far in advance of their European contemporaries in the knowledge of nature and in the application of that knowledge to human improvement (Fisher 1982).This neglect of the scientific

contributions of non-western civilizations not only has implications for minority students but also for the perceptions of majority students regarding the contribution and abilities of non-western peoples.

The remainder of the paper will touch on the variety of resource materials that are available and expand (due to limitations in space) on a limited number of them.

MAYA MATHEMATICS AND CALENDAR

The most sophisticated examples of Maya thought are exemplified by their calendar and the mathematics which precede it. Many years of astronomical observation and meticulous record keeping were necessary in order to achieve the accuracy which they attained. For example, they calculated the difficult cycle of Venus with only an error of 0.08 day in every 481 years; they developed tables to predict eclipses of the sun ,and, they could calculate dates thousands of years into the past or the future.

The structure of the calendar is determined both by their cosmological beliefs and by the nature of their mathematical system itself. The Mayans did not use fractions or decimals.They were therefore forced to use stratagems, such as lowest common multiples, that would yield results in whole numbers. Cosmologically, the general belief in Mesoamerica was that the world had been destroyed and recreated several times. Thus ,their concept of time was circular and cyclical ,rather than our concept of linear,non-repetitive time. One form of the calendar was composed of two separate and interlocking calendars: 1) a 260 day "sacred" calendar and 2) a 360 day "agricultural or secular" calendar. A given day would have a different name in each calendar, for example 4-Ahau in the "sacred" and 18-Cumku in the "agricultural" calendar. These two names would not occur together on the same day within an interval equal to the least common multiple of 260 and 360 i.e. 18,980 days (52 years). This time interval (the Calendar Round) was used throughout Mesoamerica and was the sole calendric unit used by the Aztecs. The Mayans used an additional system, the Initial Series or Long Count, which

will be discussed after an introduction to Mayan mathematical conventions.

Mayan mathematics were vigesimal, i.e., powers of base 20 rather than of base 10 as in our decimal system. They also employed place value notation (discussed later) and were one of only two cultures to independently discover the use of zero. The European knowledge of zero came through contact with Islamic culture at the end of the Middle Ages. The Arabs in turn had learned this concept in India,where it had been discovered some years after the discovery of the same principle by the Mayans in the New World. Only three symbols are used to represent numbers in this system: one unit (•), five units (—) and zero ( ). In this article we will use (0) to stand for zero. Place value notation is vertical rather than horizontal as is the case with our number sustem i.e. 1,10,100,1000,10000 etc. Examples follow:

	x^0	x^1	x^2	x^3	x^4
Maya	1	20	400	8000	160,000
M.calendar	1	20	360	7200	144,000
decimal	1	10	100	1000	10,000

As can be seen, when dealing with the calendar, the progression was modified by changing the third unit to 20 x 18 = 360. The Maya units of time follow:

1 day = kin
20 kin = uinal
18 uinal = tun (360 days)

20 tun = katun (7200 days)

20 katun = baktun (144,000 days)

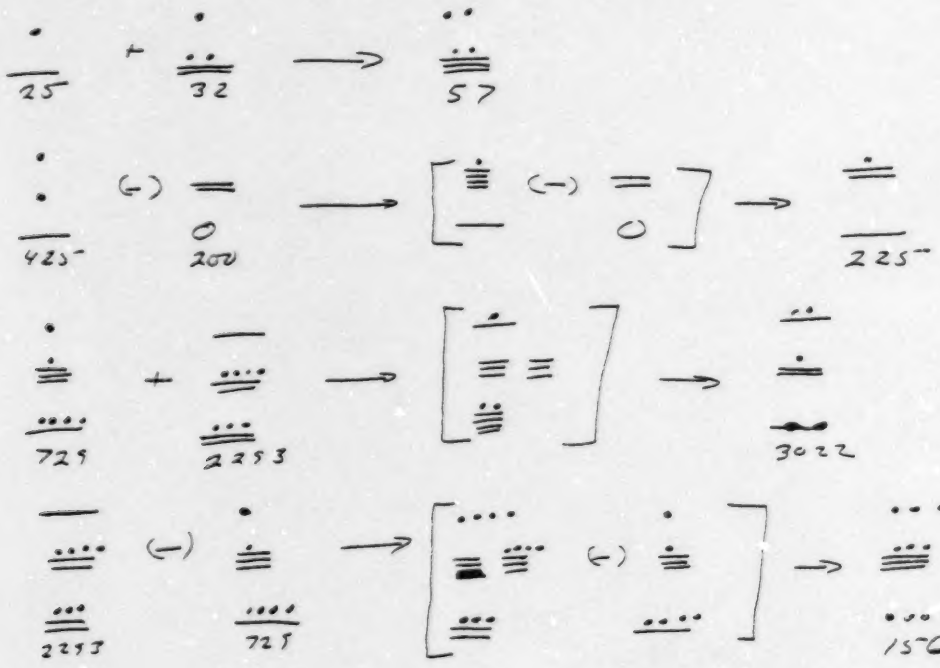
etc.

The other advance which made accurate time-keeping possible was the designation of a starting date from which the calendar was to be counted. Calendric zero dates are based on events which may be either historic or mythologic. Our own uses the birth of Christ as the starting point. The Maya used a date that is too ancient to be historical. Perhaps it was the start of the latest creation of the world. The Initial day was, 4-Ahau 8-Cumku (the names in the two aforementioned calendars) at the end of period of 13 baktuns which corresponds to the date August 10, 3113 B.C. in the Julian Calendar. When we say, August 31, 1978, we mean that 1 (1000 year unit)+ 9 (100 year unit)+ 7 (10 year unit)+8 (1 year unit)+ 8 (1 month unit)+31 (1 day unit) have transpired since the initial date of our calendar. In an exactly analogous fashion, a Maya date : 9.17.0.0.0. 13-Ahau 18-Cumku means that 9(baktun)+17 (katun)+0 (tun)+ 0(uinal)+ 0 (kin)have passed since the initial date arriving at a day called 13-Ahau in the "sacred" calendar and 18-Cumku in the "secular" calendar. Further information on the Maya calendar is available in a number of references (Ortiz de Montellano 1979b; Aveni 1980:133-210;Morley 1975).

Several articles have appeared on the use of the Mayan system for arithmetic calculations (Sanchez 1961; Anderson 1971; Lambert,Ownby-McLaughlin and McLaughlin 1980). George Sanchez, the pioneer in this area,used to teach his system to school children in Austin, Texas, and claimed that with a small amount of instruction they could perform arithmetic operations faster in Mayan than in the decimal system, particularly if they used an abacus arrangement (Sanchez 1963). In the classroom, Mayan arithmetic can be used to illustrate the concept of place notation in a more dramatic fashion than with a decimal system; it can illustrate the concept of expressing numbers as powers of different bases, especially if it is used in conjuction with base 2 used in computer language. It also gives a graphic illustration of the concept of borrowing and carrying from one register to another in

addition and subtraction. It can be used to get children to deal comfortably with numbers in different systems, to have them play with numbers, and in general to demonstrate that mathematics can be fun. Examples of how these operations are carried out follow.

Addition and subtraction are carried out in a straight-forward manner, remembering to carry when appropriate. That is: five dots= one bar and four bars = one dot in the next higher register, and vice-versa.



Sanchez recommends that these operations be carried out with counters (a nickel for a bar, a penny for a dot and a bottle cap or people for zero) and found that focusing on the visual pattern and carrying out intermediate operations as one goes on (rather than writing them out as we did above in the last subtraction) is the real secret for rapid and easy calculation (1961 : 23).

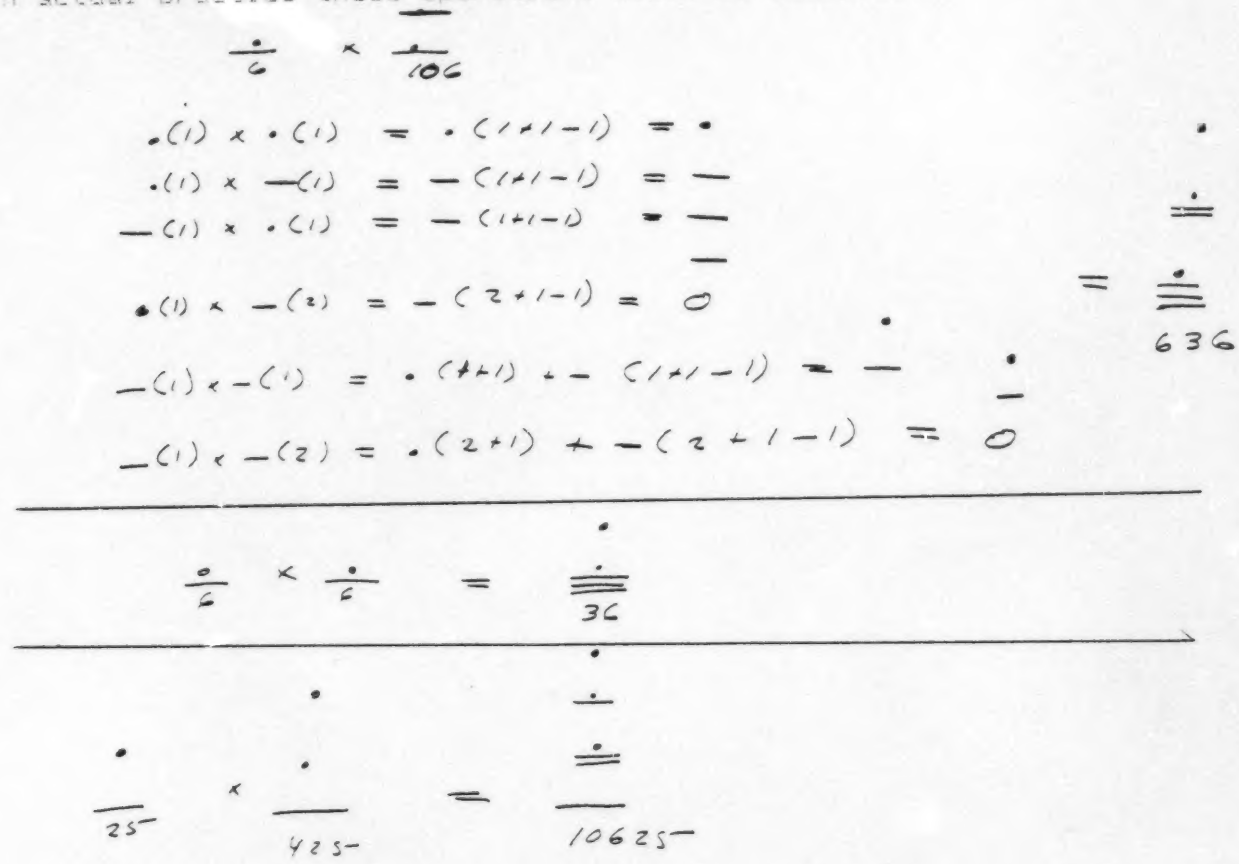
Multiplication will be described in more detail. Remember that five dots convert to a bar in the same register (vertical position) and that four bars convert to a dot in the next higher register. These rules can be formalized (Lambert,Ownbey-McLaughlin and McLaughlin)

dot (n) x dot (m)= dot (n+m-1) n,m = register number

bar (n) x dot (m)= bar (n+m-1)

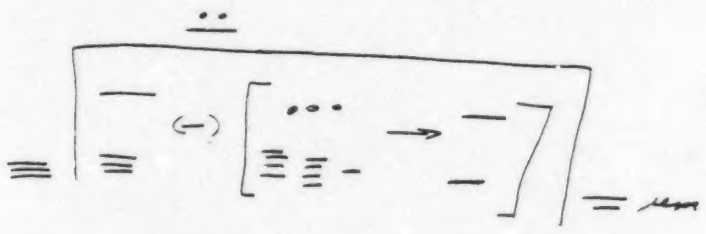
bar (n) x bar (m) = dot (n+m) + bar (n+m-1)

For analytical purposes we will do one multiplication by multiplying each element at a time and combining the products at the end, although in actual practice these operations would be combined.



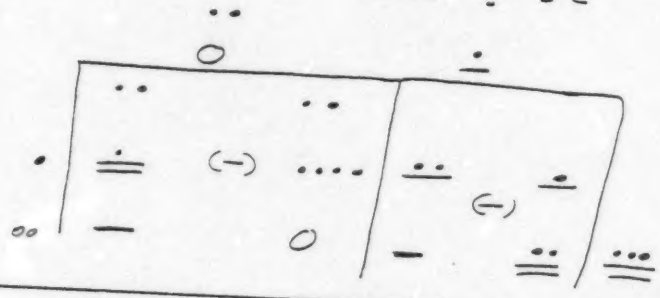
Division is essentially the reverse of multiplication. As in Arabic, but without reference to multiplication tables, a "trial" quotient is obtained by dividing the highest number of the divisor into the highest, or, that failing, into the highest and the next highest numbers of the dividend, etc.

115 ÷ 15



ans = 7 rem 10

1025 ÷ 22



ans 46 rem 13

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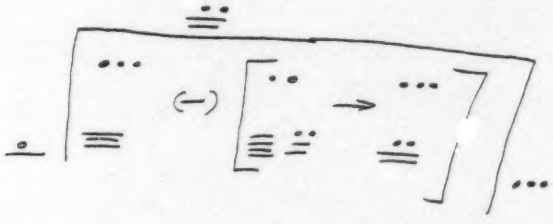
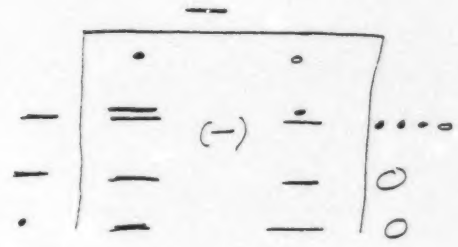
75 ÷ 6



ans 12 rem 3

12105 ÷ 2601



ans 5 rem 1600

While today we do not rely on naked eye observations to survive, the growing and popular field of archeoastronomy is not only breaking new grounds as to how ancient man used the heavens, but is also providing us with a resource to teach science. The use of this resource not only develops observational skills and helps teach scientific methodology, but also helps to develop pride in the contributions and skills of our ancestors.

Information on the astronomical knowledge of the New World can be found in the books Skywatchers of Ancient Mexico by Anthony F. Aveni, The First Stargazers by James Cornell, In Search of Ancient Astronomies and Echoes of the Ancient Skies by E. C. Krupp. The material presented in this portion of the paper is a brief description of the information presented in these books. The last book by Krupp was recently published and is just beginning to be found in the bookstores. All four books, in particular Cornell's, are suitable for teachers and students with elementary knowledge of astronomy.

Selected sites in Mesoamerica and the United States will be chosen and described. Before proceeding, it is important to review some of the naked eye observations that ancient man made and that can be made today by students.

The most obvious observation that can be made is that the day is divided into a light and a dark period and that these periods are not always equal. It is not obvious, though, that this is the result of the earth's rotation on its axis. To an observer on Earth what is apparent is that the heavenly bodies, the stars, the sun,the moon, and the planets move at varying speeds, rising in the East and setting in the West. We cannot sense that the Earth is moving. In addition, the sun, the moon and the planets can be viewed against the background of stars as reference points. Let us describe some of the general observations that can be made daily, monthly, or yearly for each of these groups of heavenly bodies.

In order to locate ourselves or a point on Earth, we use a grid or coordinate system consisting of latitude and longitude, with the Equator and Prime Meridian serving as the reference points, respectively. This system is called the Earth Coordinate System. In order to locate objects in the heavens, two systems can be used. 4the

Horizon Coordinate System and the Equatorial Coordinate System. Because ancient man made most of his observations by sighting objects at the horizon or above the horizon, the Horizon Coordinate System will be briefly explained.

Using a general diagram we can show the coordinates that are used in the Horizon Coordinate System (Figure 1). The point directly above the observer's head is called the zenith. A line running north and south, passing through the poles and the zenith is called the meridian. The sun, moon and stars rise in the East, reach their highest point, culmination, and set in the West. The distance above the horizon is called the altitude. The direction of the object is measured toward's one right when facing north and is called the azimuth. The azimuth and the altitude of any object changes continually, so it is not constant with respect to time nor with the location of the object. The axis of the Earth points to a spot where the stars seem to stand still or to make small circular paths. This spot is where the North Star is located and is called the Pole Star for this reason.

The Equatorial Coordinate System is used to describe the changing aspect of the heavens. It employs a reference frame which moves with the stars as the Earth rotates. This system will not be described here.

STARS: To describe the movement of the stars, the observer's position needs to be designated, since observations will be different in different locations. For an observer at the North Pole (Figure 2a), the stars never rise and set. The same constellations are always seen, but they seem to trace circular paths above the horizon. For an observer at the Equator (Figure 2b), the stars rise in the East and set in the West, with no variation throughout the year. This can be seen more clearly, if the observer faces East. The observer will see the imaginary straight lines the stars trace as they appear to move from East to West.

For an observer in the northern temperate zone, between the pole and the equator (Figure 2c), the stars trace a slanted path, rising in the East, moving slightly South to reach their highest point in the sky, then moving slightly North to set in the West. The rising and

setting stars shift slightly every day, thus different stars and constellations appear above the horizon at different times of the year. While we cannot sense it, this is a response to the changing position of the earth with respect to the sun.

SUN In general, it is true that the sun rises in the East and sets in the West, but the rising and setting positions shift, and are related to the seasons. In addition, the altitude, how high above the horizon the sun travels, also varies with the season. Noon is used as a reference point, it is the time when the sun reaches its highest altitude for a given day. To see the sun at noon, an observer in the northern temperate zone would always look South. In Mesoamerica, the observer could also look directly up or North, depending on the season. In the north temperate zone (Figure 3), about the altitude of Michigan or of some of the Medicine Wheels we will be discussing later, an observer sees the sun in Winter (winter solstice) rising southeast and setting southwest. In the Spring and Autumn (equinox), the observer sees the sun rising directly East and setting directly West. Only twice a year can we correctly state that the sun rises in the East and sets in the West.In the Summer (summer solstice), the observer can see the sun rising northeast and setting northwest. Figure 4 shows the same observations, but for an observer in a low northern latitude, where Mesoamerica is situated. The dates corresponding to each of the noted rising and setting points are also included. This diagram clearly shows that to see the sun in a low northern latitude during the summer solstice, the observer must look North and high above the northern horizon. At this latitude, the sun can also be directly overhead twice a year. The sun not only appears to be moving with respect to its rising and setting points and across the sky, but also up and down. Today we know that it is the 23.5º tilt of the earth on its axis (Figure 5) that causes the seasons. As the Earth orbits the sun, the earth's axis remains pointed in the same direction.

If we view the sun against the background of stars, we observe that the groups of stars traversed during the year do not change. These groups of stars, or constellations, make up what we call the zodiac. In astronomy, this path is called the <u>ecliptic</u>. The sun moves 1º, or twice its own diameter per day along the ecliptic from west to

East, making a complete cycle of 360° in one year. Consequently, the star patterns or constellations will appear to shift their position relative to the sun. Because we follow sun time, we would see a star rise a few minutes earlier each day. The first day of the year when any particular star can be seen just before dawn is known as its heliacal rising, i.e., when it is near the sun. The last night on which a star can be seen just after sunset is known as the heliacal setting. For example, some Indians in the Southwest still divide their year by the position of the Pleiades, the Seven Sisters: summer heliacal rising - time to plant; zenith at dawn - end of planting; past zenith -harvest begins; one quarter down from zenith- deer-hunting time; and heliacal setting- harvest feast. This particular constellation is also important to the Indians of Mesoamerica.

MOON: The moon orbits the Earth as the Earth orbits the sun, but its apparent motion and cyclic changes are complex and will not be discussed.

PLANETS: Five of the planets, Mercury, Venus, Mars, Saturn and Jupiter are visible with the naked eye. They move independently and somewhat erratically along the ecliptic, never straying more than 11° from the center of the ecliptic. While we will not discuss their complex motion, it is important to mention that in Mesoamerica, the appearance of Venus above the horizon as the morning or evening star was noted with care and precision.

This brief introduction will serve as the background for the discussion of some archeoastronomically important sites. The sites North of Mesoamerica will be discussed first. Studies have concentrated in four major areas: 1. the earthern mounds of the Mississippi and Ohio valleys; 2. the solar alignments found in the wood and stone rings of the Plains; 3. the rock art found in the Southwest; and 4. the solar alignments incorporated into the permanent structures built by the agricultural societies of the Southwest.

Most of the astronomy is concerned primarily with the sun, the sunrises and sunsets of the solstices and equinoxes and the zenith passages that were used to mark the dates of religious ceremonies and agricultural practices. The planets and the brighter stars, such as Sirius and Aldebaran were also watched as they rose and set along the

horizon. The moon was also used to keep track of time, but not by marking horizon positions, and will therefore not be discussed.

From about 1000 B.C. to about 500 A.D., the North American Indians were engaged in large building projects. The Mound Builders, as they have come to be called, built huge geometrical earthworks of circles, squares and octagons (Figure 6a,b). It is believed that this activity began in the lower Mississippi Valley and spread westward and northward along the tributaries into Illinois, Ohio and West Virginia. Is is also believed that the idea to build these mounds came from Mesoamerica. Thousands of these prehistoric constructions exist, but most have not been excavated or studied. Their construction required considerable surveying skills, knowledge of geometry and community organization. These mounds are considered too large to be altars, and they are not burial grounds. Did they have a purpose? Astronomical measurements are being done at some sites, but this work is hampered by the fact that the patterns are large and can be better viewed from the air. They have also been eroded by the centuries or have been destroyed by farming, highways, and urbanization.

More information is available on the mounds found in Canokia, Illinois (Figure 7) where the remains of several circles formed by stockades or rings of posts have been found. Because of its similarity to Stonehenge in England, is supposedly a solar observatory. It has been called an American Woodhenge. Alignments have been found that mark the solstices, and it has also been suggested that it was also used to predict eclipses.

Other circles have been found in the culture of the Plains Indians who inhabited the area North of Texas to Canada and between the Mississippi basin and the Rocky Mountains. The Plains Indians, like the Mound Builders, left no written records. Consequently, when early pioneers discovered these circles traced in stones, they misnamed them "Medicine Wheels" because they believed that they were used by Medicine Men. All the sites are situated on mountains or the highest land around, where the horizon can be viewed without obstruction. Many are simply huge central cairns, surrounded by rings of stones 100 to 200 feet across with or without spokes. The better known examples are Wyoming's Big Horn Medicine Wheel (Figure 8) and Moose Mountain Medicine wheel in Canada. Both show alignments to the

summer solstice and to the stars Sirius, Aldebaran, and Rigel (heliacal rising). No alignments were found with the winter solstices, but most of these sites are inaccessible in the winter and were not used during this time.

In the Southwest, the Indians incorporated their knowledge of astronomy and its study into folklore, religion, rock art, and into buildings and other structures. The buildings and structures have been classified into two types (Cornell 1981 : 154)and they will be briefly described because the description of the specific ruins will make more sense.

Type I consists of man-made structures that are generally used in conjunction with some natural feature on the horizon in order to gain information about the sun's motion. The Wijii ruins in Chaco Canyon, New Mexico are an example of this type. There is a white sun symbol painted at the top of a stone stairway and some five hundred meters to the east-southeast, in the direction of the mid-winter sunrise, there is a natural cleft in the stone face of a high butte rising over the horizon. An observer standing at the "sun painting" and watching the sun rise in the gap would be able to determine the date of the solstice within a day or two.

Type II consists of man-made structures designed so that certain astronomical phenomena will become obvious through the interplay of light and shadow. There are a number of examples of this type, the most well known being Casa Grande, an ancient adobe temple in Arizona, and Casa Rinconada, one of the great kivas, or ceremonial rooms, of Pueblo Bonito in Chaco Canyon, New Mexico (Figure 9). Both have been found to align accurately with the sun at solstices and equinoxes.

It is the petroglyph on Fajada Butte in Chaco Canyon that has caused the greatest excitement in North American archeoastronomy , for it suggests that the ancient sun-watchers in the Southwest were more sophisticated than once thought(Frazier 1979). The marker found indicates that the Anasazi or "Ancient Ones" were also concerned with zenith oriented astronomy. With this marker, the zenith passage of the noon -day sun during the solstices and equinoxes could be determined. The marker consists of three sandstone slabs leaning against the cliff

face. On the cliff, behind the steps, are two petroglyphs. One is a large nine-ring spiral and the other a small three-ring spiral. As the sun shines, a thin dagger-shaped ray of light moves vertically down the spiral, its precise movement dependent on the season (Figure 10).

As we go further South into Mesoamerica, we find that there, the natives of the New World reached their highest level of organization and sophistication. Mesoamerica is defined as the region bounded on the North by the Tropic of Cancer and on the South by the northern border of Honduras. The various civilizations which rose and fell in the area shared a number of culture traits. These include mathematics in base 20 and the cyclical approach to the calendar. The period from about 300 A.D. to 900 A.D., when Europe was in the Dark Ages, coincides with the time when the civilizations of Mesoamerica reached their highest sophistication. The ceremonial centers and buildings of this period will be used as examples for our discussion.

Mesoamericans were practicing basic science in the sense that they were making observations and were making predictions derived from their observations. The fact that these predictions were used, not to understand nature per se but to manipulate possible omens of an astrological nature, is irrelevant. They were concerned with space and time, and used their knowledge of astronomy to plan the orientation of Mesoamerican ceremonial centers such as Teotihuacan and the Main Temple of Tenochtitlan (the capital of the Aztecs) as well as for building individual buildings with particular shapes and orientations that could be used as astronomical observatories. The two best known and studied are El Caracol at Chichen Itza in Yucatan and Building J in Monte Alban near Oaxaca, Mexico.

Teotihuacan, the largest and most famous of all the ceremonial centers in Mesoamerica, is north of Mexico City and governed an empire (for nearly a thousand years) that ranged from central Mexico to northern Guatemala. Its influence and heritage affected every subsequent Mesoamerican culture. The contribution we are interested in is the influence that Teotihuacan had in the use of astronomical orientation for the arrangement of ceremonial centers and individual buildings. Teotihuacan is oriented on a grid. The North-South axis, the Avenue of the Dead, is 15.5° east of astronomical North. This skewing to the East of North occurs in 88% of the sites measured to

date. It ranges from as little as 7º to 23º East of North. Recent investigations by Aveni suggest that the orientation is related to the Pleiades (Aveni, Hartung and Buckingham). The Pleiades can be viewed by sighting along a line between two petroglyphs or "pecked crosses" as Aveni calls them. These "pecked crosses" are small dots, or circles, chipped on a rock to form " a double circular pattern centered on a set of orthogonal axes". When a line between these two petroglyphs is extended to the western horizon, it marks the place where the Pleiades set in 150 B.C., when Teotihuacan was constructed. At this time, the Pleiades also rose heliacally on the same day that the sun made its zenith passage. The validity of this choice is buttressed by the great importance accorded to this constellation in Mesoamerica, particularly in the case of the Aztecs. The pecked crosses can be found in a variety of locations, from as far north as the United States border in Texas to as far south as Guatemala, which indicates the extent of the influence of Teotihuacan. It has been suggested that the pecked crosses also served other purposes, such as calendars, as part of a game and in art.

Tenochtitlan, the Aztec capital, was also oriented East of North. In addition, the orientation of its most important building, the Templo Mayor, made it possible to use it in conjunction with the round Temple of Quetzalcoatl as an observatory for the equinox sunrise. We have evidence from preconquest writings, from a 1524 map attributed to Cortez, and actual measurements, to support the use of positional astronomy by the Aztecs ,a civilization which did not possess as much astronomical knowledge as the Maya (Aveni 1980: 247-248).

The two buildings that have been designated as astronomical observatories are not only unusual in orientation but also in shape. El Caracol at Chichen Itza in Yucatan is the most famous. It was described by Sir Eric Thompson in these words: "Every city sooner or later erects some atrocious building that turns the stomach: London has its Albert Hall;New York, its Grant's tomb; and Harvard , its Memorial Hall. If one can free oneself from the enchantment which antiquity is likely to induce and contemplate this building in all its horror strictly from an aesthetic point of view, one will find that none of these is quite so hideous as the Caracol of Chichen Itza. It stands like a 2-decker wedding cake on the square carton in which it

came. Something was pretty clearly wrong with the taste of the architects who built it."(Thompson 1943: 10).

El Caracol looks like a modern observatory and consists of a circular tower with doors facing the cardinal points. Within the tower is a circular corridor from which four more doors, facing midway between the cardinal points, lead to another circular corridor. This inner circular corridor surrounds a masonry core which has a small circular staircase leading to the top and from which the structure gets its name. Near the top of the structure is a flat area from which open three rectangular horizontal shafts, facing West, Southwest and South. The tower sits on top of two platforms and was built by the Maya about 800 A.D. The directions of the faces of the Lower and Upper Platforms appear to have been laid out to point to horizon events of the sun and Venus. The doorways show alignments with stars (Canopus, Castor and Pollux rising, Fomalhaut setting) and one with the sun(Figure 11). The windows also point to horizon events of the sun and Venus (Aveni 1975:1980). Other round structures resembling the Caracol exist in Mesoamerica, but none have been carefully measured and analyzed for astronomical orientations.

The most unusual building in Mesoamerica is probably building J at Monte Alban, a Zapotec ruin in Oaxaca Mexico. It is pentagonal in shape and is out of line in orientation from all other structures by about 45°, and no two sides or angles are equal. If one draws a perpendicular line northeastward from the outer stairway of Building J, it passes directly through the doorway atop Building P, a rectangular building, and then strikes the horizon at the rising position of Capella, the sixth brightest star in the sky. At the time that Monte Alban was built, Capella underwent its heliacal rising on the same date as the first solar zenith passage at Monte Alban. This zenith passage could then be viewed from a chamber inside Building P because only at this time did the light penetrate down a vertical shaft leading to the surface of the building (Figure 12).

The civilizations of Mesoamerica represent the heritage of Mexico, and therefore of the Mexican-Americans and Native Americans in the United States.Only a limited number of sites were described, but they illustrate the amount of resources available for use by the teacher. It is not in a form readily used by teachers and students.

but a small amount of work can render it pedagogically useful.

PROJECTS

The following are a list of projects that a teacher could use in teaching science and mathematics, as well as other topics. They are designed to develop the observational skills of the student, strengthen their inquiry skills as well as learn some basic mathematic and scientific facts.

1. Have the students sight where the sun sets or rises monthly throughout the year. The observations can be plotted on a graph in the classroom or recorded by the construction of a "medicine wheel" in the playground. The same observations can be made by using a set of slides that were taken at Michigan State University of the setting sun throughout the year. The students can then describe the motion of the sun throughout the year and relate its position to the seasons, weather, and agriculture They can even use of the sun to determine the direction in which they are traveling. The students can also be introduced to the idea that the same set of observations may be explained in different ways, and why one explanation is chosen over another, i.e. the motion of the sun can be explained by either a sun-centered universe or an Earth- centered universe. This will begin to help students realize that they are not learning absolute truths, and that we do many things because scientists have agreed to communicate using conventional symbols.

2. Have the students measure the altitude of the noonday sun monthly throughout the year. The observations can be plotted on a graph. The students can develop a variety of methods for measuring altitude- from using their arms in a right angle and estimating the altitude with their eyes to developing mechanical devices. More advanced students might invite a surveyor to talk to the class. A set of slides showing the sun at Michigan State University throughout the year is also available to show as a summary. Again, the altitude of the sun can be related to the seasons, weather and direction. The students can also learn different ways of measuring time by constructing a sun dial or a water clock. Learning angles and angular measurements in mathematics in this less abstract fashion will probably be more interesting to students and make learning more effective.

3. For more advanced students of the motion of the heavenly bodies, computer games could be developed that would help to teach astronomical facts. The settings could be in a number of places on Earth, thereby integrating a variety of topics such as art, geology, geography and anthropology.

4. Go star gazing or visit a planetarium or both. These activities can be used as an observational exercise if done several times a year with records of the evening sky kept visible in the classroom. One can also discuss the myths or stories associated with the heavenly bodies and the creation stories of the universe or of the earth developed by different cultures (Soustelle; Thompson 1966). These myths or stories may then be contrasted with the myths or stories associated with Old World civilizations.

This exercise can be coordinated with a creative writing class or an English class. Students can write either descriptive paragraphs or explanatory essays about their observations.

5. Present a slide show of Mayan, Aztec and other Indian ruins. The students can then either draw pictures relating what they saw or construct models of some of the major ceremonial centers or of as specific buildings such as El Caracol, paying particular attention to orientation. More advanced students can examine local buildings in the city to determine astronomical orientation. This latter exercise has already been done by students in Charleston, South Carolina and is called Charlestonhenge (Dukes 1982). In addition, the celestial sphere can be used as a data generating device for the Mesoamerican area (Mullins and Wilson 1979). We have presented such a slide show to students as young as those in the first grade. It was difficult to get through the show, because they had so many questions.

6. At the college level, a science course for the nonscientist can be developed around the Mesoamerican ruins, such as the one that was developed by Professor Bayless based on Stonehenge. The course integrated material in astronomy, chemistry, geology and physics (Bayless 1977).

7. Orientation games can be played using familiar landmarks first, then astronomical observations, and then a compass to find a treasure or a reward. The game may be developed by the teacher, with

the students interpreting the information given, or the students can develop their own set of instructions. This enables the students to learn about coordinate systems and how they are utilized to locate oneself or an object on Earth. This activity can also be integrated with wilderness survival skills, such as those that helped the Indians survive.

Beyond astronomy, other aspects of the civilizations of the New World can be used to teach basic science concepts and information. The following are areas that can be expanded:

1. Geology -Volcanic activity has always been a fact of life in Mesoamerica. This interesting phenomenon may be used to teach basic concepts in geology while studying culture. The trade items of the Mesoamericans were of volcanic origin (obsidian, serpentine, basalt and jade). The cenotes (sinkholes in limestone) can be used as a starting point for the geological phenomenon of underground rivers and the composition of land in Yucatan.

2. Botany-Ethnobotany

a. The different uses and sources of many plants can be discussed with particular attention to how the Indian civilizations have contributed to food resources.

b. In teaching classification, ethnobotanical classifications should also be presented (Berlin, Breedlove and Raven 1973:1974; Ortiz de Montellano 1976b). These are logical and their nomenclature is descriptive of the plant rather than a reflection of the name of the discoverer's name as is too often the case in Linnean classification. The point can also be made that a classification scheme is used because a group of people agree to use it as a standard. The Linnean system is European folk biology elevated by agreement to a science and perfected in the past 200 years. Students can be encouraged to develop their own taxonomic system in order to teach them the logic of the process involved.

3. Agriculture Many of the practices we use today in agriculture have their basis on Indian practices. In fact, we may be returning to a modified version of them today. The Aztecs developed chinampas (built up platforms on shallow lakes) which were drought-proof and could produce several crops a year (Armillas 1971; Coe 1964) Other of their

foods show promise for relieving protein shortages and assisting in reducing the energy cost of agriculture (Folan,Fletcher and Kuntz ; Wiseman ;Turner and Harrison; Furst ; Cole;Felker and Bandurski;Citerri).

4.Nutrition Nutritional information can be presented in the context of the typical food of Mexico, of Mexican Americans and of Native Americans(Anderson,Calvo,Serrano and Payne;Katz,Hediger and Valleroy).Much information on this is available from the Cooperative Extension Program, since it is used in their Expanded Nutrition Program.

5.Architecture and City Planning- How are cities planned today? How were cities planned in the past?(Hardoy 1964) How did the Indians use the resources available in the land they lived? For example, in the southwest, adobe is a popular building material. Why is it uniquely suited for that environment? What building techniques are used when using adobe? Would a knowledge of such sciences as astronomy and chemistry be a must for a good architect?

6. Art- There are a number of ways to integrate art and science:

a. In studying color and color production, natural plants can be collected and classified for the biology section; the natural dyes can be extracted for beginner's chemistry; and the dyes can be used in an art project (Friedstein; Baryonitz; Littmann; Sequin-Frey).

b. A unique resource in Michigan is the Diego Rivera murals at the Detroit Institute of Arts. These can be used to study art, science and technology. Dorothy McMeekin has studied the scientific aspects of these murals (1982). In them, Rivera placed a special emphasis on the positive and the negative aspects of science and of technology. He depicts the applied sciences of surgery, pharmacy, agriculture and the chemical industry and weaponry. His representations of theoretical science extend back to the ancient Greek concepts of Earth, Fire, Air and Water and proceed through the 19th Century debate in geology over the role of fire and water to the 20th Century discussion of the origin of life and the mechanism for the synthesis of life. Dr. McMeekin is in the

process of developing curricular materials about the murals for teachers.

The above discussion outlines briefly some activities which can be used to teach topics in science and mathematics to Hispanic school children. The approach is consistent with the purpose of providing pride in their heritage of providing an "intellectual role model" which up to now has been lacking. Much more work needs to be done to develop materials in the detail needed for direct use by the teacher in the classroom. We hope that this paper will stimulate efforts in this direction.

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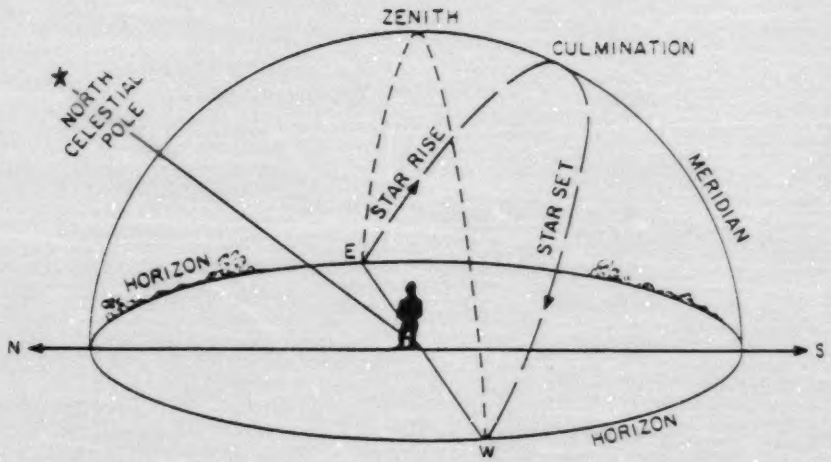


Figure 1. Horizon Coordinate System (Aveni 1980)

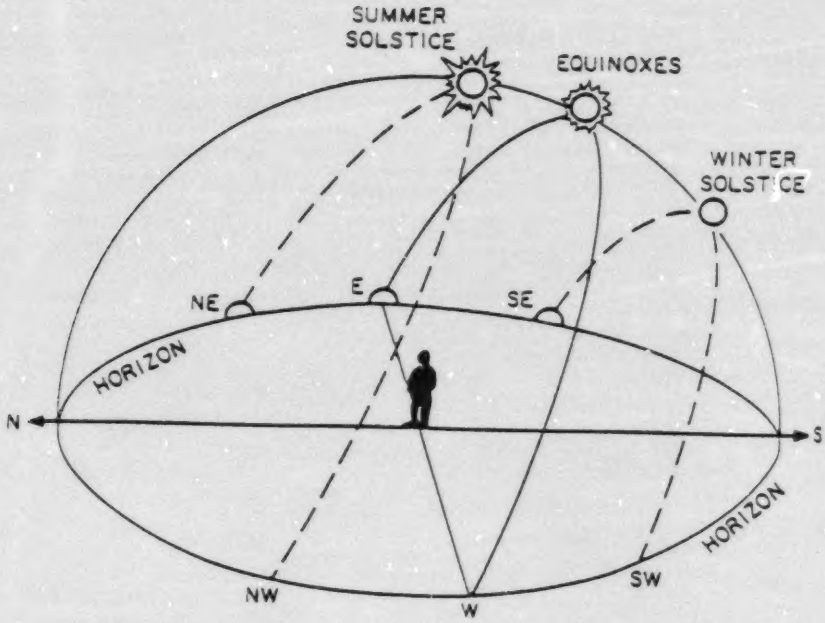


Figure 3. North temperate Zone (Aveni 1980)

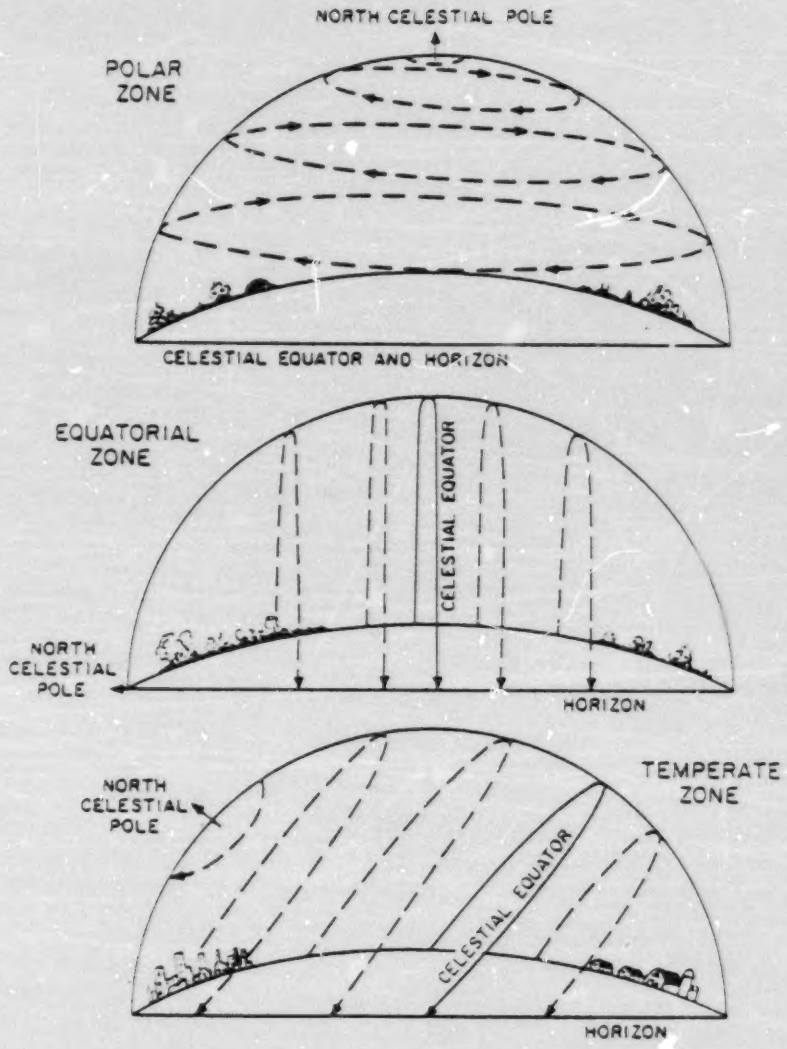


Figure 2. Horizon at several locations (Aveni 1980)

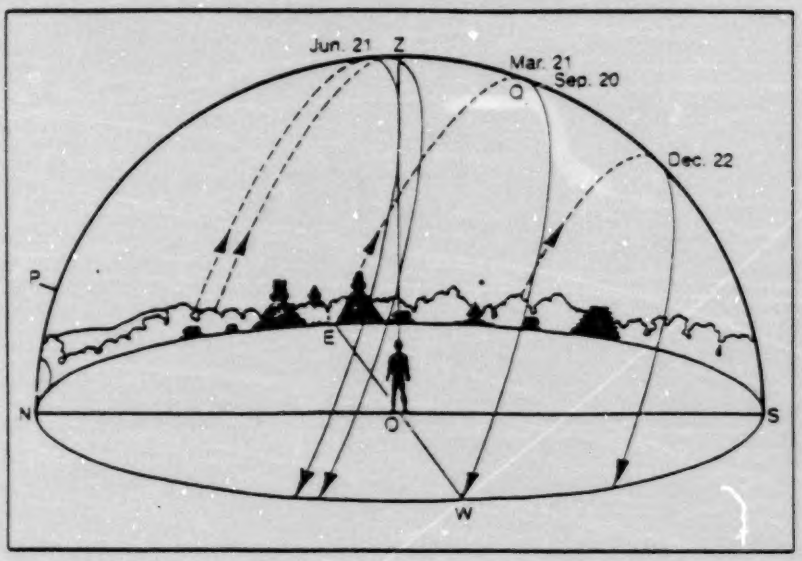


Figure 4. Mesoamerica (Aveni 1980)

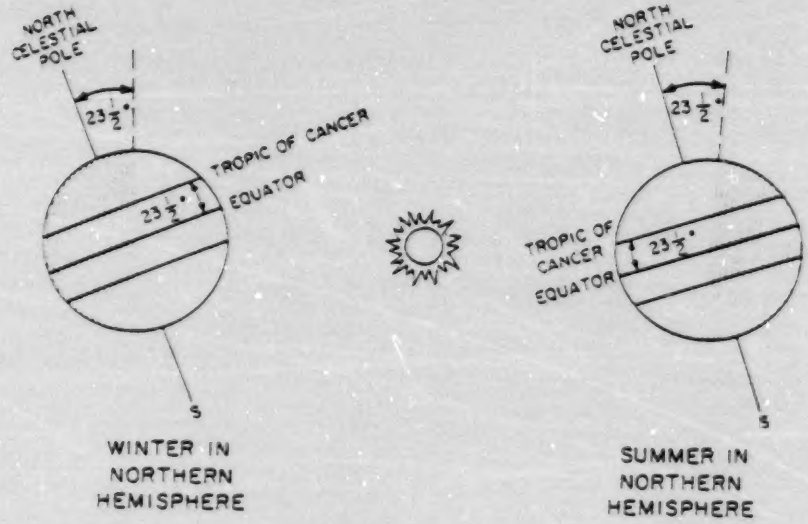
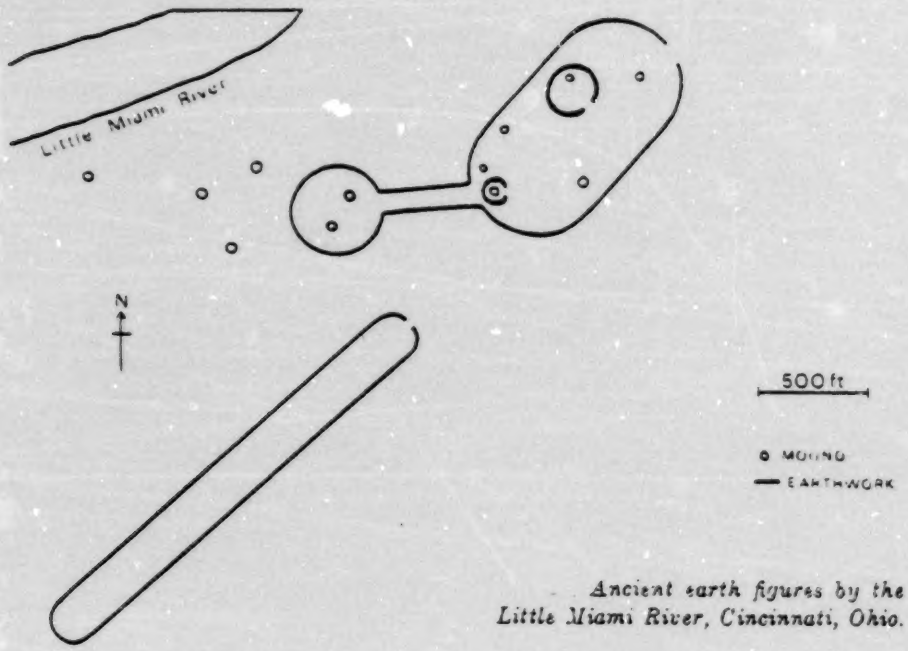
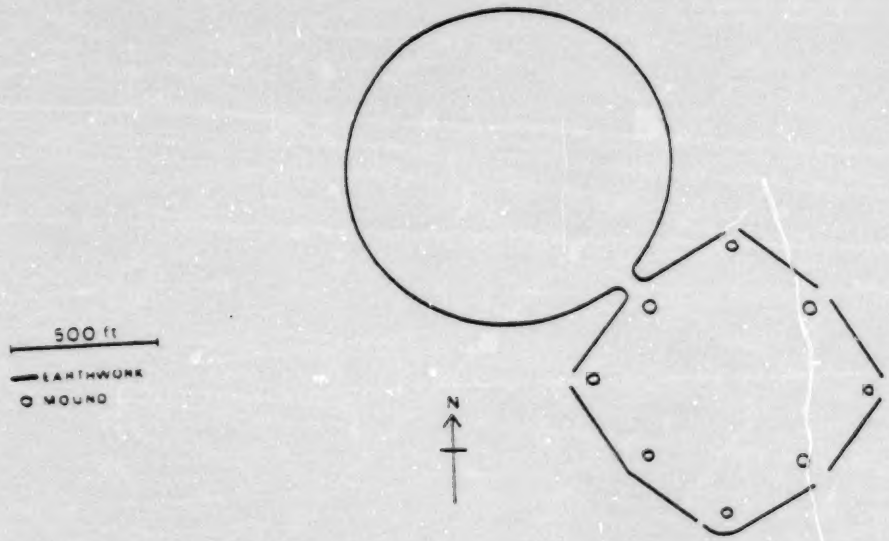


Figure 5. Tilt of the Earth (Aveni 1980)



Ancient earth figures by the Little Miami River, Cincinnati, Ohio.

Figure 6a. Mounds (Hawkins 1973)



Geometric embankments near the Scioto River, Ohio.

Figure 6b. Mounds (Hawkins 1973)

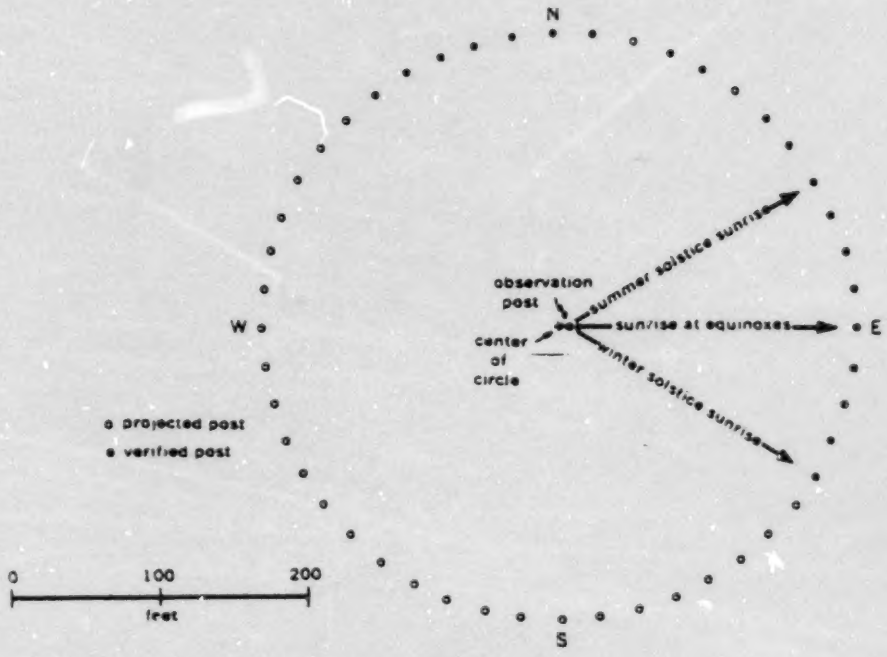


Figure 7. Cahokia, Illinois (Hawkins 1973)

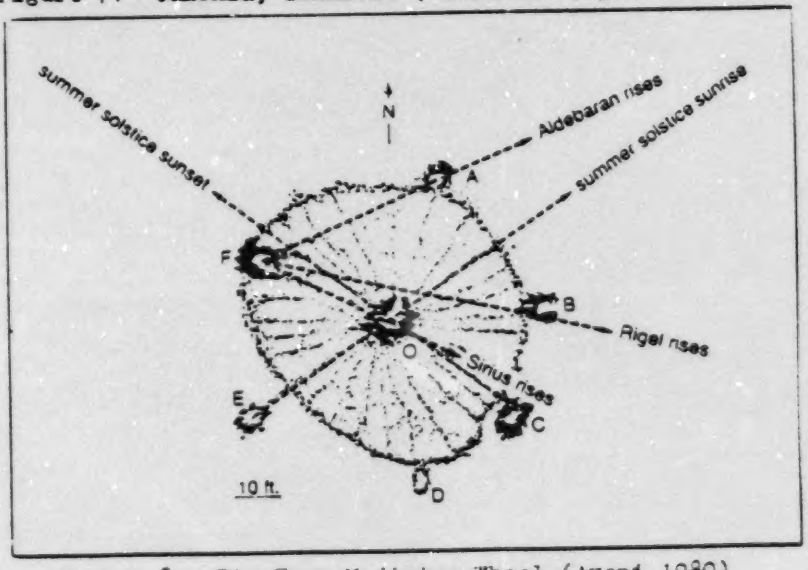


Figure 8. Big Horn Medicine Wheel (Aveni 1980)

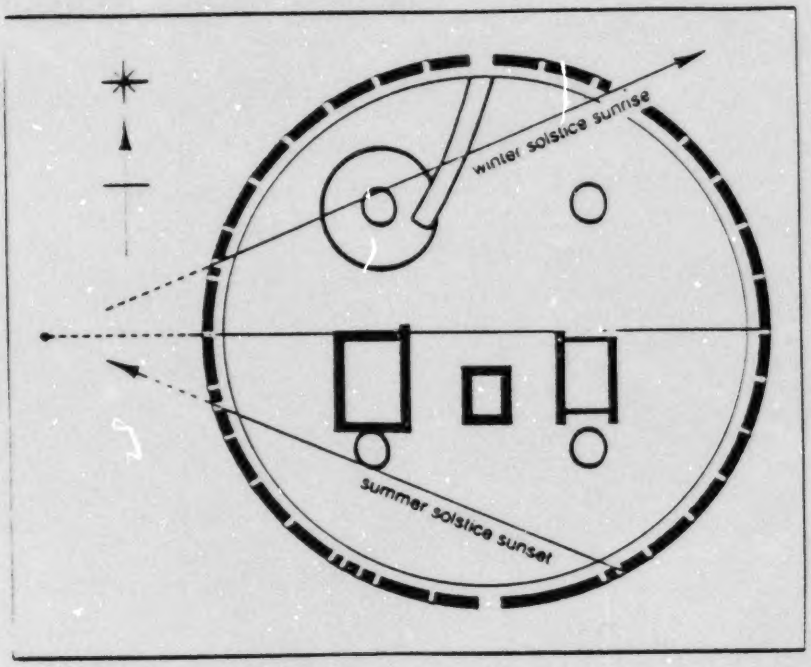


Figure 9. Casa Rinconada, Chaco Canyon (Aveni 1980)

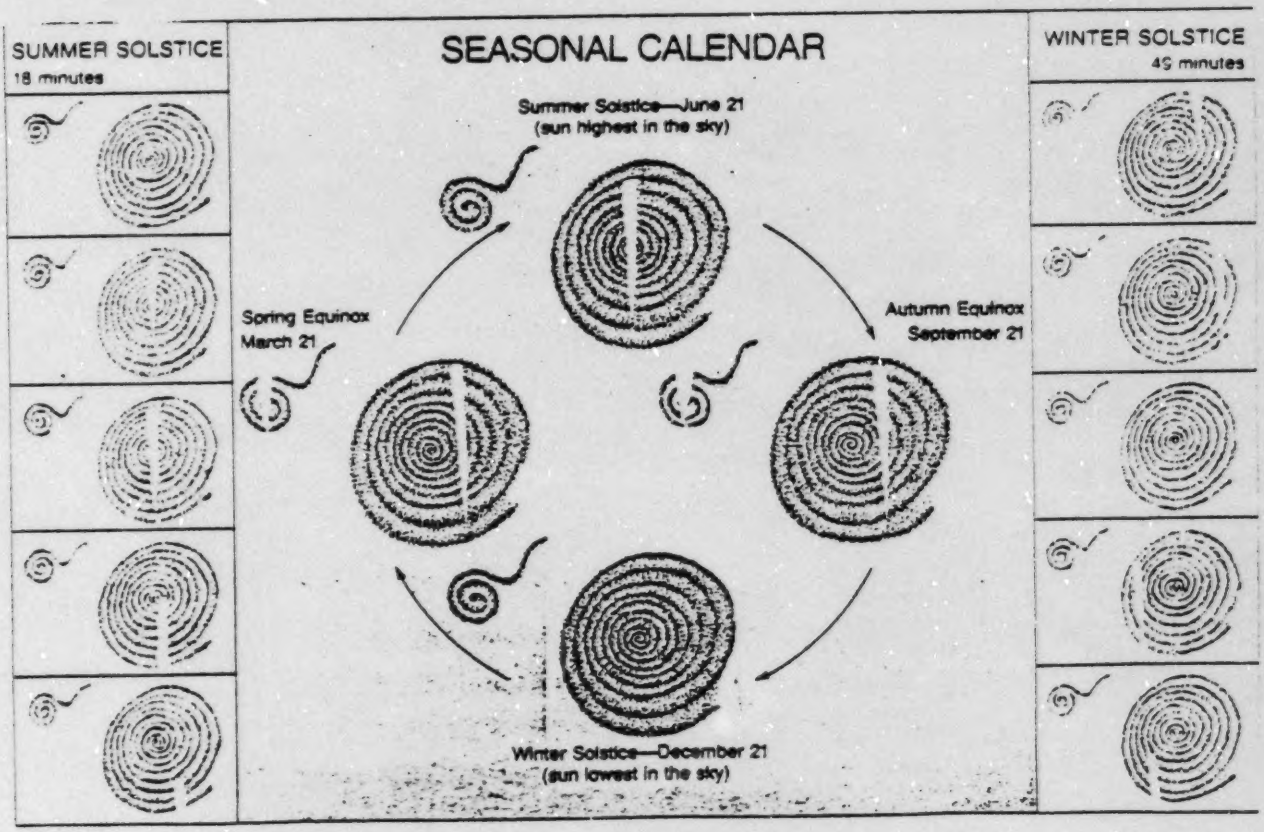


Figure 10. Petroglyph, Fajada Butte, Chaco Canyon (Frazier 1979)

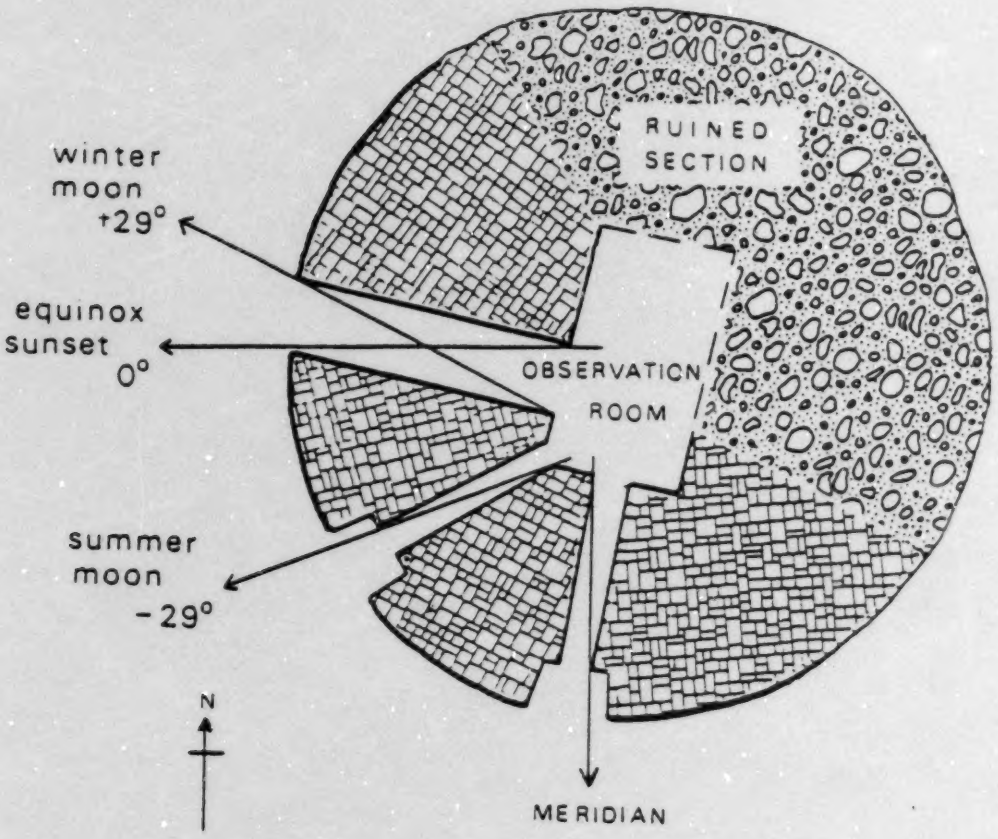


Figure 11. Caracol Chichen Itza (Hawkins 1973)

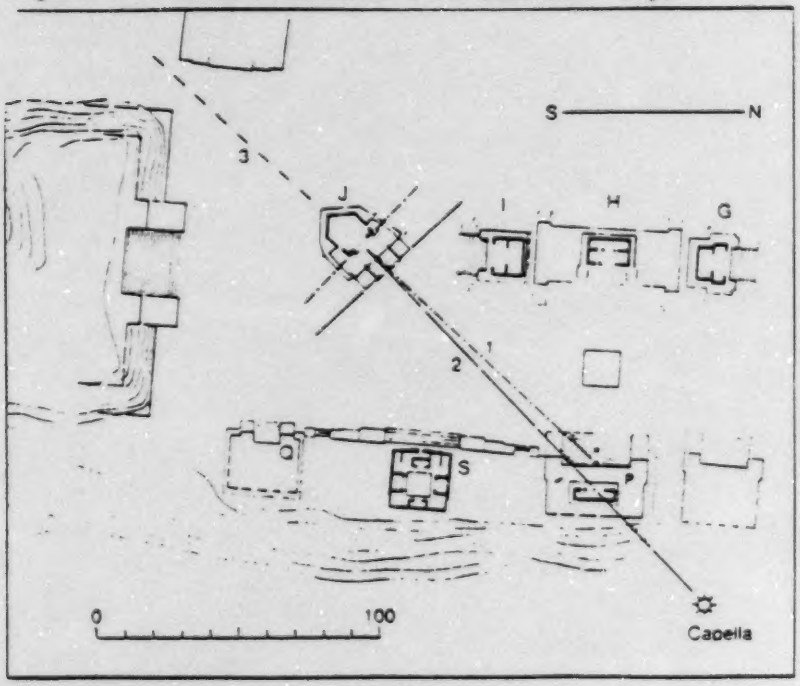


Figure 12. Alignments, Building J, Monte Alban (Aveni 1980)